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Impact of wastewater use on soil properties of Kurukshetra and Charkhi Dadri district

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Abstract
The present study deals with the assessment of changes in chemical characteristics of soils, irrigated with sewage water, in Kurukshetra and Charkhi Dadri areas of Haryana, India. Samples were collected (0-15 and 15-30 cm) from sewage and tube well water irrigated soils at various sites, where these waters are directly used for irrigating the crops. Soil pH, electrical conductivity (EC), organic carbon (OC), cation exchange capacity (CEC), calcium carbonate ($CaCO_3$) exchangeable cations, macro and micro nutrients and heavy metals were estimated from these soils. The mean value of pH (8.20) was found highest in the soils irrigated with sewage water of Kurukshetra. The mean value of EC (0.72 dSm^{-1}) was found highest in the soils of Charkhi Dadri irrigated with sewage water. The mean value of OC (1.01%), $CaCO_3$ (1.99%) and CEC (18.50 cmol (+) kg^{-1}) was found highest in soils of Kurukshetra irrigated with sewage water. The content of exchangeable cations like Ca^{2+}, Mg^{2+}, Na^+ and K^+ were observed higher in soils irrigated with sewage water as compared to soils of irrigated with non-sewage water. The mean value of Ca^{2+} (8.78 cmol (+) kg^{-1}), Mg^{2+} (4.98 cmol (+) kg^{-1}) and Na^+ (2.42 cmol (+) kg^{-1}) was found highest in the soils irrigated with sewage water of Kurukshetra. But the mean value of K^+ (1.49 cmol (+) kg^{-1}) was found highest in the soils irrigated with sewage water of Charkhi Dadri. The mean value of N (184.75 kg ha^{-1}), P (28.91 kg ha^{-1}) and K (271.50 kg ha^{-1}) was found highest in the soils irrigated with sewage water of Kurukshetra. The content of micronutrients like (Zn, Cu, Fe and Mn) and heavy metals like (Cd, Cr, Pb and Co) were observed higher in soils irrigated with sewage water as compared to soils of irrigated with non-sewage water. The mean value of Zn (3.78 mg kg^{-1}) and Cu (2.40 mg kg^{-1}) was found highest in the soils irrigated with sewage water of Charkhi Dadri. But the mean value of Fe (18.23 mg kg^{-1}) and Mg (16.19 mg kg^{-1}) was found highest in the soils irrigated with sewage water of Kurukshetra. The Cr content was not detected in all the soils samples collected from different cities from sewage and non-sewage water irrigated sites. The mean value of Cd content was higher in sewage irrigated soil as compared to non-sewage irrigated soil. The mean value of Pb (0.51 mg kg^{-1}) and Co (0.18 mg kg^{-1}) was found highest in the soils irrigated with sewage water of Charkhi Dadri. The study suggests that sewage water irrigation led to beneficial changes in chemical properties of the soil, but increased the soil contamination of heavy metals. However, the intermittent use of clean water in such areas may not only reduce the metal contamination in the plants but will also maintain soil fertility.

Keywords: Sewage and non-sewage water, heavy metals, micronutrients, CEC, soil fertility

Introduction

Soil is a vital natural resource which provides food, fodder and fuel for the basic needs of human and animal. Continuous growth of human and animal population increases the demand on soils for more food production. The increased population needs more urban area for shelter and industries for employment resulting into gradual increase in the sewage and industrial effluent. The raw sewage water contains beneficial as well as toxic metals. Sewage water is mainly composed of more than 95 per cent water, pathogens such as bacteria, viruses and parasitic worms, non-pathogenic bacteria, organic particles, soluble organic material, pharmaceuticals, inorganic particles etc. The growth of towns, cities, and development of industries by 19th century has led to problem of disposal of sewage, which encouraged the use of sewage water in irrigation. The practice of use of domestic sewage in farming is becoming prevalent with the increasing demand of water. Due to fast industrial development and the growth of population, the availability of water decreases continuously. This led to increased demand of water and subsequently increased generation of waste water. Irrigation with sewage became a prevalent practice in arid and semiarid regions, where it was readily available and economic to freshwater.

Scott *et al.* (2004) [26] estimated that at least 20 million hectares in 50 countries are irrigated with raw or partially treated waste water. In developed countries waste water is treated prior to use for irrigation. However, in some developing countries where treatment costs can-not yet be afforded, waste water in its untreated form is widely used in agriculture (Hussain, 2005) [7]. Sewage and industrial effluents are the rich source of both beneficial as well as harmful elements. Since, some of these effluents are a rich source of plant nutrients; therefore, soil provides the logical sink for their disposal. However, many untreated and contaminated sewage and industrial effluents may have high concentration of several heavy metals such Cadmium (Cd), Nickel (Ni), Lead (Pb) and Chromium (Cr) (Narwal *et al.,* 1993) [17]. The composition and volume of waste water discharged vary from city-to-city, but broadly the effluents discharged into the sewage water are reported to contain similar toxic elements such as Cd, Cr, Pb, Cu, Zn, Fe, Mn etc. (Yadav *et al.*, 2003) [38]. Due to continuous use of raw sewage water the agricultural lands, particularly in peri-urban areas often exhibit elevated levels of trace elements (Rattan *et al*., 2002 and 2005) [23, 22]. Soil contamination by trace elements is important throughout because these elements are difficult to remove from soil and are heavily toxic to micro-organisms, plants and animals. They cause changes in natural and artificial ecosystem and consequently result in fatal diseases to human through the food chain. However, unlike air and water pollution, soil contamination is usually not visible; it only can be reflected through plant absorption and physiological response. Therefore, contamination of soil by these elements has more potential for disastrous effect than of either water or air pollution. The reuse of waste water for agricultural irrigation purposes reduces the amount of water that needs to be extracted from water resources (USEPA, 1992; Gregory, 2000) [34, 4]. It is the potential solution to reduce the freshwater demand for zero water discharge avoiding the pollution load in the receiving sources. The benefits of waste water use in irrigation are numerous but precautions should be taken to avoid short and long-term environmental risks. Sewage water has beneficial aspects of adding valuable plant nutrients and organic matter to soil (Liu *et al*., 2005) [13]. Domestic waste water contains essential plant nutrients such as N, P, K and micronutrients which are beneficial for plants growth. Due to the increase in the demand of water, there is a need to adopt recycle and reuse techniques to decrease the load of available resources.

The increased competition for freshwater among urban and semi-urban centers, industries and agriculture has put agriculture, particularly irrigated agriculture under severe pressure as irrigation has been the largest user of water (Van der Hoek *et al.,* 2002) [35]. Therefore, the use of treated, partially-treated or untreated waste water has received more attention. Sewage is a major load on water bodies and its incorrect disposal promotes growth of toxic algal blooms which hampers aquatic life. The practice of reuse is the necessity of the present time. Sewage has affected adversely both soil health and crop productivity. Sewage has resulted in improved physico-chemical characteristics of soil. In the agricultural practices, the irrigation quality of water is believed to have an effect on the soil characteristics, crops production and proper management of water (Shainberg and Oster., 1978) [27]. Particularly, application of saline/sodic water results in the reduction of crop yield and deterioration of the physical and chemical properties of soil. Therefore, it has more concern to the farmers when being used as an irrigant, which may contain constituents capable of creating adverse effects on the soil media and the agriculture produce. Availability of water for biomass production is diminishing continuously due to the competing demands for fresh water from different sectors. Because of limited availability of the good quality water for irrigation, sewage water is being increasingly used in the peri-urban agricultural activities (Sree Ramulu., 1994 [30]; Taywade and Prasad, 2008) [33]. The continuous use of raw sewage water generally leads to build up of metals and organic residues in the soils depending upon composition, rate and frequency of sewage-irrigation as well as characteristics of the soils (Singh and Sakal., 2001; Saraswat *et al*., 2005; Taywade and Prasad., 2008) [29, 25, 33]. Keeping in view aforementioned facts, the study impact of wastewater use on soil properties of Kurukshetra and Charkhi Dadri District was undertaken.

Materials and Methods

The study was conducted in Haryana in northern India, situated between 27°39' to 30°35' N latitude and between 74°28' and 77°36' E longitude. Three sites were selected namely Narwana, Jind and Charkhi Dadri. Under each districts, four sites were selected for the sampling of sewage and non-sewage source of water for irrigation at 0-15 and 15-30 cm depth. From each site, two samples were taken from each depth and the mean values of the soil properties estimated in laboratory were presented in tabulated form. The soil samples were first air dried ground with wooden pestle and mortar and passed through 2 mm stainless steel sieve. After mixing thoroughly, the processed samples were stored in cloth bags and used for various chemical properties, using standard methods.

Samples analysis

Soil pH was determined in a 1:2.5 soil water suspension by glass electrode pH meter (Piper, 1950) [20]. Electrical conductivity of supernatant liquid was determined by using conductivity meter (Piper, 1950) [20]. Soil organic carbon content was determined by Walkely and Black (1934) [37] method. Soil calcium carbonate content was determined by Puri (1949) [21]. Exchangeable calcium and magnesium were determined in neutral normal ammonium acetate extract by Versenate titration method (Cheng and Bray, 1951) [1]. Sodium was determined by flame photometer with the help of a standard curve outlined by Jackson (1967) [8]. Potassium was determined by flame photometer with the help of a standard curve outlined by Jackson (1967) [8]. Cation Exchange capacity was determined in the extract obtained by leaching the soil with normal sodium acetate solution (pH 8.2) followed by complete washing with 95 per cent ethanol and final extraction with normal ammonium acetate. Sodium in the resultant extract was determined with the help of flame photometer (Hesse, 1971) [6]. Available nitrogen in soil sample was determined by adopting the alkaline permanganate method of (Subbiah and Asija, 1956) [31]. The phosphorus content of soil was estimated following the method as described by Olsen *et al.* (1954) [18]. Soil available phosphorus was extracted using 0.5 M $NaHCO_3$ (pH 8.5) and determination was done by ascorbic acid method as described by Miller and Keeney (1982). The transmittance or absorbance of the blue color so developed was read after 10 minutes, on spectrophotometer at 660 nm wavelength. The available potassium was extracted with neutral normal ammonium acetate with flame photometer (Jackson, 1973) [9].

Total Zn, Cu, Mn, Fe, Cd, Pb, Co, and Cr were estimated in acidified digested samples using atomic absorption spectrophotometer (AAS). The statistical analysis was accomplished by Statistical Software Package for Agricultural Research Workers (Sheoran *et al*. 1998) [28].

Results and Discussion

The quality of sewage and well waters was assessed for irrigation with respect to their different parameters. The data pertaining to pH, EC, OC, $CaCO_3$ CEC and exchangeable cations of sewage and non-sewage water irrigated soils is presented in Table 1 to 2.

Effect on soil chemical properties

The range of pH values of sewage water irrigated soil were recorded from 8.12 to 8.27, 7.76 to 7.92 as compare to non-sewage water irrigated soil were recorded from 7.84 to 7.90, 7.30 to 7.47 of Kurukshetra and Charkhi Dadri respectively. The value pH was found highest (8.12 to 8.27) in the sewage water irrigated soil of Kurukshetra as compare to Charkhi Dadri (7.84 to 7.90). The mean value of pH was found highest at both sewage water (0.72) and non- sewage water (0.36) irrigated soil of Kurukshetra as compared to Charkhi Dadri. The value of pH increased with depth of soil. These results revealed the sewage water applied in soils make the soil alkaline in nature. This might be due to fact that soluble salts (Ca, Mg, Na, and K) and heavy metals (Cd, Pb and Co) were present in the sewage water more as compared to the non-sewage water. The results are in confirmation with the results of Rattan *et al.* (2005) [22], Gloaguen *et al.* (2007) [3] and Gwenzi and Munondo (2008) [5].

The range of EC values of sewage water irrigated soil were recorded from 0.37 to 0.41, 0.70 to 0.74 dSm^{-1} as compare to non- sewage water irrigated soil were recorded from 0.19 to 0.21, 0.30 to 0.41 dSm^{-1} of Kurukshetra and Charkhi Dadri respectively. The value EC was found highest (0.70 to 0.74 dSm^{-1}) in the sewage water irrigated soil of Charkhi Dadri as compare to Kurukshetra (0.37 to 0.41 dSm^{-1}). The mean value of EC was found highest at both sewage water (0.72 dSm^{-1}) and non- sewage water (0.36 dSm^{-1}) irrigated soil of Charkhi Dadri as compare to Kurukshetra. The value of EC decreased with depth of soil. Higher EC of the soil indicates the presence of higher levels of anions and cations in the soil. Further the sewage water was rich in the salts mainly of sodium chloride which also increased the EC of the soil. The results are in confirmation with the results of Gloaguen *et al.* (2007) [3], Gwenzi and Munondo (2008) [5] and Omran *et al.* (2010) [19].

The range of OC values of sewage water irrigated soil were recorded from 0.89 to 1.13, 0.66 to 0.79% as compare to non-sewage water irrigated soil were recorded from 0.54 to 0.63, 0.48 to 0.59% of Kurukshetra and Charkhi Dadri respectively. The value OC was found highest (0.89 to 1.13%) in the sewage water irrigated soil of Kurukshetra as compare to Charkhi Dadri (0.66 to 0.79%). The mean value of OC was found highest at both sewage water (1.01%) and non- sewage water (0.59%) irrigated soil of Charkhi Dadri as compare to Kurukshetra. The value of OC increased with depth of soil. The organic carbon in the sewage water irrigated soil was found to be higher which ultimately improved the infiltration rate, CEC and decreased the bulk density. All these properties are helped to improve the crop productivity point of view. Similar results were reported by Kesba *et al.* (2010) [10], Verma *et al.* (2013) [36] and Subramani *et al.* (2014) [32].

The range of $CaCO_3$ values of sewage water irrigated soil were recorded from 1.80 to 2.18, 1.00 to 1.08% as compare to non-sewage water irrigated soil were recorded from 0.54 to 1.05, 0.63 to 1.75% of Kurukshetra and Charkhi Dadri respectively. The value $CaCO_3$ was found highest (1.80 to 2.18%) in the sewage water irrigated soil of Kurukshetra as compare to Charkhi Dadri (1.00 to 1.08%). The mean value of $CaCO_3$ was found highest (1.99%) in the sewage water irrigated soil of Kurukshetra as compared to the non-sewage water irrigated soil (1.19%) of Charkhi Dadri. The value of $CaCO_3$ increased with depth of soil. The increase in calcium carbonate content in sewage water irrigated soil might be due to precipitation of Ca^{2+} exchanged from the soil complex by Na^{+}, present in sewage water as reported by Narwal and Gupta (1989) [16].

The range of CEC values of sewage water irrigated soil were recorded from 17.62 to 19.37, 13.79 to 14.88 cmol (+) kg^{-1} as compare to non-sewage water irrigated soil were recorded from 12.92 to 13.03, 8.43 to 8.91 cmol (+) kg^{-1} of Kurukshetra and Charkhi Dadri respectively. The value CEC was found highest (17.62 to 19.37 cmol (+) kg^{-1}) in the sewage water irrigated soil of Kurukshetra as compare to Charkhi Dadri (13.79 to 14.88 cmol (+) kg^{-1}). The mean value of CEC was found highest at both sewage water (18.50 cmol (+) kg^{-1}) and non-sewage water (12.98 cmol (+) kg^{-1}) irrigated soil of Kurukshetra as compare to Charkhi Dadri. The value of CEC decreased with depth of soil. Further, an increase in soil organic matter resulted into increase the CEC of soil irrigated with sewage water as compared to lower organic matter in the soils irrigated with non-sewage water. The results are in confirmation with Mitra and Gupta (1999) [15], Datta *et al.* (2000) [2], Reddy and Rao (2000) [24] and Malla and Totawat (2006) [14].

Exchangeable cations

The content of exchangeable cations like Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} were observed higher in soils irrigated with sewage water as compared to soils of irrigated with non-sewage water. The mean value of Ca^{2+} content in the soils of Kurukshetra, and Charkhi Dadri at 0-15 cm depth irrigated with sewage water was 8.78 and 6.10 (cmol (p+) kg^{-1}) while at 15-30 cm depth it was 6.27 and 4.57 (cmol (p+) kg^{-1}) respectively. The mean value of Ca^{2+} content of Kurukshetra and Charkhi Dadri soils at 0-15 cm depth irrigated with non-sewage water was 8.78 and 6.10 (cmol (p+) kg^{-1} while at 15-30 cm depth had 3.42 and 2.38 (cmol (p+) kg^{-1}, respectively. It is inferred from the data that sewage water irrigated soils had higher accumulation of Ca^{2+} than other cations. The mean value of Mg^{2+} content in Kurukshetra and Charkhi Dadri soils at 0-15 cm depth irrigated with sewage water was 4.98 and 2.73 [cmol (p+) kg^{-1}] while at 15-30 cm depth it was 3.92 and 1.58 [cmol (p+) kg^{-1}, respectively. It is inferred from the data that Mg^{2+} content decreased with increased depth under sewage water application in the fields at all the sites. The non-sewage water application resulted into lesser Mg^{2+} content in soils at all the sites at 0-15 and 15-30 cm depths as compared to soils irrigated with sewage water. Sodium (Na^{+}) and K^{+} content in sewage water irrigated soils at both the depths on all the sites were found higher as compared to soils irrigated with non-sewage water. However Na^{+} and K^{+} content decreased with increase in depth at all the sites. The mean value of Na^{+} content in the soils of Kurukshetra irrigated with sewage water at 0-15 cm and 15-30 cm was found higher [2.42 and 1.74 cmol (p+) kg^{-1}] as compared to all other sites while K^{+}

ions was found highest in Charkhi Dadri [1.49 and 0.90 cmol (p+) kg^{-1}].
The range of exchangeable cations like Ca^{2+}, Mg^{2+} and Na^{+} was found highest (8.39 to 9.17, 4.45 to 5.51, 1.88 to 2.96 cmol (+) kg^{-1}) in the sewage water irrigated soil of Kurukshetra as compare to Charkhi Dadri (5.47 to 6.72, 2.15 to 3.31, 1.06 to 1.31 cmol (+) kg^{-1}). But the range of K^{+} was found highest (1.24 to 1.74 cmol (+) kg^{-1}) in the sewage water irrigated soil of Charkhi Dadri a as compare to Kurukshetr (0.66 to 0.77 cmol (+) kg^{-1}). The value of exchangeable cations like Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} decreased with depth of soil. The increase in the exchangeable cations might be due to the fact that these cations are higher in the sewage water which on irrigation simultaneously results into the higher concentration of these cations. Similar results were observed by Gloaguen *et al.* (2007) [3], Gwenzi and munondo (2008) [5] and Kumar *et al.* (2011) [12].

Available macro-nutrients

Data pertaining to available macro-nutrients irrigated with sewage and non-sewage water from different cities in Haryana are presented in Tables 3 to 4.The range of N values of sewage water irrigated soil were recorded from 168 to 201.50, 148 to 161 kg ha^{-1} as compare to non-sewage water irrigated soil were recorded from 115.88 to 121.45, 62.90 to 87.50 kg ha^{-1} of Kurukshetra and Charkhi Dadri respectively. The value N was found highest (168 to 201.50 kg ha^{-1}) in the sewage water irrigated soil of Kurukshetra as compare to Charkhi Dadri (148 to 161 kg ha^{-1}). The mean value of N was found highest at both sewage water (184.75 kg ha^{-1}) and non-sewage water (118.67 kg ha^{-1}) irrigated soil of Kurukshetra as compare to Charkhi Dadri. The value of N decreased with depth of soil. The range of P values of sewage water irrigated soil were recorded from 27.35 to 30.46, 20.50 to 35.16 kg ha^{-1} as compare to non-sewage water irrigated soil were recorded from 15.40 to 17.10, 13.64 to 16.60 kg ha^{-1} of Kurukshetra and Charkhi Dadri respectively. The value P was found highest (27.35 to 30.46 kg ha^{-1}) in the sewage water irrigated soil of Kurukshetra as compare to Charkhi Dadri (20.50 to 35.16 kg ha^{-1}). The mean value of P was found highest at both sewage water (28.91 kg ha^{-1}) and non-sewage water (16.25 kg ha^{-1}) irrigated soil of Kurukshetra as compare to Charkhi Dadri. The value of P decreased with depth of soil.
The range of k values of sewage water irrigated soil were recorded from 261 to 282, 232.50 to 243.80 kg ha^{-1} as compare to non-sewage water irrigated soil were recorded from 158.40 to 171.10, 98.30 to 151.20 kg ha^{-1} of Kurukshetra and Charkhi Dadri respectively. The value k was found highest (261 to 282 kg ha^{-1}) in the sewage water irrigated soil of Kurukshetra as compare to Charkhi Dadri (232.50 to 243.80 kg ha^{-1}). The mean value of k was found highest at both sewage water (271.50 kg ha^{-1}) and non-sewage water (164.75 kg ha^{-1}) irrigated soil of Kurukshetra as compare to Charkhi Dadri. The value of k decreased with depth of soil. Similar results were reported by Datta *et al.* (2000) [2], Yadav *et al.* (2003) [38] and Gwenzi and Munondo (2008) [5].

DTPA extractable micro-nutrients and heavy metals of sewage and non-sewage water

Data pertaining to the DTPA-extractable micronutrients like Zn, Cu, Fe and Mn and heavy metals like Cd, Cr, Pb and Co are presented in Tables 5-6. The content of micronutrients like Zn, Cu, Fe and Mn were observed higher in soils irrigated with sewage water as compared to soils of irrigated with non-sewage water. The range of micronutrients like Zn, Cu, Fe and Mn from (2.32 to 2.75, 2.11 to 2.61, 17.23 to 19.23, 14.87 to 17.51 mg kg^{-1}) in the sewage water irrigated soil of Kurukshetra. The range of micronutrients like Zn, Cu, Fe and Mn from (3.75 to 3.81, 2.36 to 2.43, 12.18 to 14.9, 8.48 to 9.26 mg kg^{-1}) in the sewage water irrigated soil of Charkhi Dadri. The mean value Zn and Cu was found highest (3.78 and 2.40 mg kg^{-1}) in the sewage water irrigated soil of Charkhi Dadri as compare to Kurukshetra (2.54 and 2.36 mg kg^{-1}). The mean value of Fe and Mn was found highest (18.23 and 16.19 mg kg^{-1}) in the sewage water irrigated soil of Kurukshetra as compared to Charkhi Dadri (13.54 and 8.87 mg kg^{-1}). The value of micronutrients like Zn, Cu, Fe and Mn decreased with depth of soil. The sewage water contained all these DTPA extractable micro elements in higher amounts as compared to the non-sewage water. This resulted into their higher contents in the soils applied with sewage water. Similar results were reported by Yadav *et al.* (2003) [38], Kharche *et al.* (2011) [11] and Zan *et al.* (2013) [39].
The DTPA extractable heavy metals like Cd, Pb and Co were higher in the soils irrigated with sewage water at both the depths (0-15 and 15-30 cm) as compared to soils irrigated with non-sewage water. The Cr content was found nil all the soils samples collected from different cities from sewage and non-sewage water irrigated sites. The mean value of Cd content was approx. same both the sites not more difference in sewage irrigated soil but the content was higher as compare to non-sewage irrigated soil. The range of Pb values of sewage water irrigated soil were recorded from 0.20 to 0.22, 0.45 to 0.57 mg kg^{-1} as compare to non-sewage water irrigated soil were recorded from 0.05 to 0.06, 0.19 to 0.21 mg kg^{-1} of Kurukshetra and Charkhi Dadri respectively. The value of Pb was found highest (0.4 to 0.57) in the sewage water irrigated soil of Charkhi Dadri as compare to Kurukshetra (0.20 to 0.22 mg kg^{-1}). The mean value of Pb was found highest at both sewage water (0.51 mg kg^{-1}) and non- sewage water (0.20 mg kg^{-1}) irrigated soil of Charkhi Dadri as compare to Kurukshetra. The value of Pb decreased with depth of soil.
The range of Co values of sewage water irrigated soil were recorded from 0.12 to 0.15, 0.15 to 0.20 mg kg^{-1} as compare to non-sewage water irrigated soil were recorded from 0.07 to 0.07, 0.08 to 0.09 mg kg^{-1} of Kurukshetra and Charkhi Dadri respectively. The value of Co was found highest (0.15 to 0.20 mg kg^{-1}) in the sewage water irrigated soil of Charkhi Dadri as compare to Kurukshetra (0.12 to 0.15). The mean value of Co was found highest at both sewage water (0.18 mg kg^{-1}) and non- sewage water (0.09 mg kg^{-1}) irrigated soil of Charkhi Dadri as compare to Kurukshetra. The value of Co decreased with depth of soil. The major source of heavy metals in the sewage water is metal plating industries, combustion of fossil fuels and mining and electroplating. The direct discharge of the wastes from these industries into the sewage water resulted into increase in the heavy metal which upon irrigation increased the heavy metals in the agricultural land. However, in the present study all the heavy metals from all five sites were found below the permissible limit (FAO, 1985). Similar results were reported by Rattan *et al.* (2002) [23], Datta *et al.* (2000) [2] and Kharche *et al.* (2011) [11].

Table 1: Effect of sewage and non-sewage water on soil pH, EC, OC $CaCO_3$ CEC and exchangeable cations of Kurukshetra

Location	Depth (cm)	pH	EC (dSm^{-1})	OC (%)	$CaCO_3$ (%)	CEC [cmol (p+) kg^{-1}]	Exchangeable cation [cmol (p+) kg^{-1}]			
							Ca^{2+}	Mg^{2+}	Na^+	K^+
SW-1	0-15	8.12	0.41	1.13	1.8	19.37	9.17	5.51	2.96	0.77
	15-30	8.15	0.33	0.83	1.96	16.10	7.41	4.48	2.06	0.33
SW-2	0-15	8.27	0.37	0.89	2.18	17.62	8.39	4.45	1.88	0.66
	15-30	8.32	0.31	0.64	3.29	12.44	5.13	3.35	1.41	0.24
Mean	0-15	8.20	0.39	1.01	1.99	18.50	8.78	4.98	2.42	0.72
	15-30	8.24	0.32	0.74	2.63	14.27	6.27	3.92	1.74	0.29
NSW-1	0-15	7.90	0.19	0.63	0.54	13.03	6.76	3.24	1.05	0.19
	15-30	7.96	0.16	0.48	0.74	7.92	3.63	3.21	1.09	0.11
NSW-2	0-15	7.84	0.21	0.54	1.05	12.92	4.63	3.31	1.21	0.12
	15-30	7.87	0.17	0.4	1.15	7.15	3.2	2.13	0.92	0.10
Mean	0-15	7.87	0.20	0.59	0.80	12.98	5.70	3.28	1.13	0.16
	15-30	7.92	0.17	0.44	0.95	7.54	3.42	2.67	1.01	0.11

SW - Sewage water, NSW - Non-sewage water

Table 2: Effect of sewage and non-sewage water on soil pH, EC, OC $CaCO_3$ CEC and exchangeable cations of Charkhi Dadri

Location	Depth	pH	EC (dSm^{-1})	OC (%)	$CaCO_3$ (%)	CEC [cmol (+) kg^{-1}]	Exchangeable cation [cmol (p+) kg^{-1}]			
							Ca^{2+}	Mg^{2+}	Na^+	K^+
SW-1	0-15	7.76	0.74	0.79	1.00	13.79	5.47	3.31	1.31	1.24
	15-30	7.81	0.61	0.45	0.75	8.74	3.65	1.23	0.93	0.67
SW-2	0-15	7.92	0.7	0.66	1.08	14.88	6.72	2.15	1.06	1.74
	15-30	8.19	0.56	0.25	1.26	11.18	5.48	1.92	0.79	1.13
Mean	0-15	7.84	0.72	0.73	1.04	14.34	6.10	2.73	1.19	1.49
	15-30	8.00	0.59	0.35	1.01	9.96	4.57	1.58	0.86	0.90
NSW-1	0-15	7.3	0.3	0.48	1.75	8.91	2.38	0.65	0.57	0.29
	15-30	7.34	0.13	0.45	1.85	6.82	2.37	0.55	0.31	0.15
NSW-2	0-15	7.47	0.41	0.59	0.63	8.43	3.10	1.00	0.67	0.21
	15-30	7.58	0.17	0.35	0.78	7.40	2.38	0.30	0.22	0.14
Mean	0-15	7.39	0.36	0.54	1.19	8.67	2.74	0.83	0.62	0.25
	15-30	7.46	0.15	0.40	1.32	7.11	2.38	0.43	0.27	0.15

SW - Sewage water, NSW - Non-sewage water

Table 3: Effect of sewage and non-sewage water on soil Available macro-nutrients of Kurukshetra

Location	Depth (cm)	kg ha^{-1}		
		N	P	K
SW-1	0-15	201.50	30.46	282.00
	15-30	186.60	27.90	266.00
SW-2	0-15	168.00	27.35	261.00
	15-30	148.20	22.20	240.50
Mean sewage	0-15	184.75	28.91	271.50
	15-30	167.40	25.05	253.25
NSW-1	0-15	121.45	17.10	158.40
	15-30	108.86	15.32	137.40
NSW-2	0-15	115.88	15.40	171.10
	15-30	103.64	13.86	157.50
Mean non-sewage	0-15	118.67	16.25	164.75
	15-30	106.25	14.59	147.45

SW - Sewage water, NSW - Non-sewage water

Table 4: Effect of sewage and non-sewage water on soil Available macro-nutrients of Charkhi Dadri

Location	Depth (cm)	kg ha^{-1}		
		N	P	K
SW-1	0-15	161.00	35.16	243.80
	15-30	156.20	31.22	203.50
SW-2	0-15	148.00	20.50	232.50
	15-30	134.60	22.30	230.90
Mean sewage	0-15	154.50	27.83	238.15
	15-30	145.40	26.76	217.20
NSW-1	0-15	87.50	16.60	98.30
	15-30	68.32	10.00	82.40
NSW-2	0-15	62.90	13.64	151.20
	15-30	51.70	12.52	95.30
Mean non-sewage	0-15	75.20	15.12	124.75
	15-30	60.01	11.26	88.85

SW - Sewage water, NSW - Non-sewage water

Table 5: DTPA extractable micro-nutrients and heavy metals of sewage and non-sewage water irrigated soils of of Kurukshetra

Location	Depth (cm)	Zn	Cu	Fe	Mn	Cd	Cr	Pb	Co
		(mg kg^{-1})							
SW-1	0-15	2.75	2.61	17.23	14.87	0.05	Nil	0.20	0.15
	15-30	2.73	2.49	15.55	13.69	0.04	Nil	0.17	0.12
SW-2	0-15	2.32	2.11	19.23	17.51	0.04	Nil	0.22	0.13
	15-30	2.46	2.03	15.03	12.39	0.03	Nil	0.18	0.12
Mean sewage	0-15	2.54	2.36	18.23	16.19	0.05	Nil	0.21	0.14
	15-30	2.60	2.26	15.29	13.04	0.04	Nil	0.18	0.12
NSW-1	0-15	0.97	1.16	10.28	5.10	0.01	Nil	0.07	0.06
	15-30	0.75	1.12	9.32	4.67	0.01	Nil	0.06	0.02
NSW-2	0-15	0.86	1.23	12.14	6.22	0.02	Nil	0.07	0.05
	15-30	0.77	1.15	10.35	4.62	0.01	Nil	0.05	0.02
Mean non-sewage	0-15	0.92	1.20	11.21	5.66	0.02	Nil	0.07	0.06
	15-30	0.76	1.14	9.84	4.65	0.01	Nil	0.06	0.02

SW - Sewage water, NSW - Non-sewage water

Table 6: DTPA extractable micro-nutrients and heavy metals of sewage and non-sewage water irrigated soils of Charkhi Dadri

Location	Depth (cm)	Zn	Cu	Fe	Mn	Cd	Cr	Pb	Co
		(mg kg^{-1})							
SW-1	0-15	3.81	2.43	12.18	9.26	0.05	Nil	0.45	0.20
	15-30	2.78	1.31	11.71	6.93	0.04	Nil	0.30	0.18
SW-2	0-15	3.75	2.36	14.90	8.48	0.03	Nil	0.57	0.15
	15-30	3.56	2.22	11.43	7.01	0.03	Nil	0.41	0.14
Mean sewage	0-15	3.78	2.40	13.54	8.87	0.04	Nil	0.51	0.18
	15-30	3.17	1.77	11.57	6.97	0.04	Nil	0.36	0.16
NSW-1	0-15	1.39	0.94	5.64	4.38	0.02	Nil	0.19	0.09
	15-30	1.29	0.78	4.13	3.56	0.01	Nil	0.15	0.05
NSW-2	0-15	2.43	1.17	4.92	5.78	0.02	Nil	0.21	0.08
	15-30	2.21	0.81	2.74	5.18	0.02	Nil	0.15	0.07
Mean non-sewage	0-15	1.91	1.06	5.28	5.08	0.02	Nil	0.20	0.09
	15-30	1.75	0.80	3.44	4.37	0.02	Nil	0.15	0.06

SW - Sewage water, NSW - Non-sewage water

Conclusion

The results of study clearly showed that chemical properties of the soil were modified by uses of waste water irrigation in Kurukshtera and Charkhi Dadri areas of Haryana. Soil pH increased, whereas EC, O C, available N, P and K, exchangeable cations, macro-micro nutrients increased under the sewage water irrigation soil. Heavy metal concentrations in the soil increased several fold at sewage water irrigated sites as compared to the clean water irrigated sites. These chemical properties of the sewage water make it safe to use it for irrigating the fields at the time of water scarcity, drought spells or under limited supply and sewage water management conditions. This can be strengthened in the peri-urban areas to reduce the cost of cultivation by providing micro nutrients from waste water.

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